Advanced Air Transportation Technologies (AATT) Project: Distributed Air-Ground Traffic Management

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AATT Project

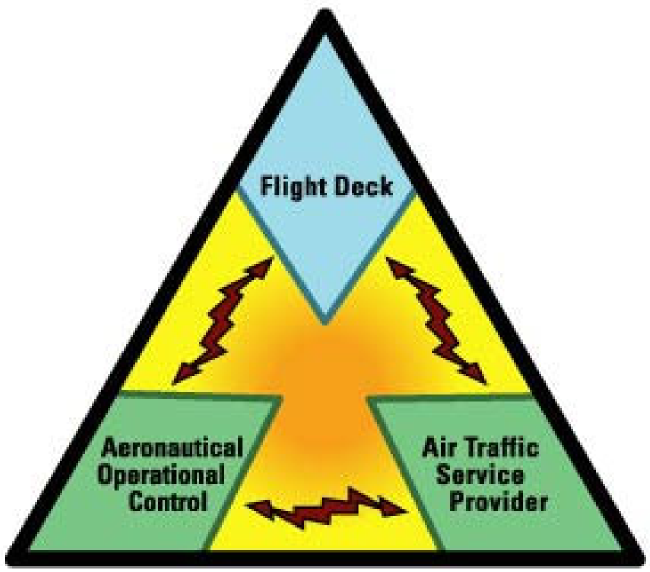
AATT Project Focus Areas

- Develop en route and terminal decision support tools (DSTs) for FAA Free Flight Phases 1 and 2
  - Enhance capabilities of present air traffic system
  - Deliver decision support tools to the FAA
- Distributed Air-Ground Traffic Management (DAG-TM) Research
  - Free Flight concept exploration
  - Evaluate feasibility of making major changes to current system and procedures
  - Deliver tested concepts to the FAA

DAG-TM Definition

- DAG-TM is the Free Flight part of AATT
- In DAG-TM flight crews, air traffic service providers, and aeronautical operational control dispatchers use distributed decision making to:
  - Enable user preferences/flexibility
  - Increase system capacity
  - Meet air traffic management requirements
- NASA is investigating the feasibility of DAG-TM concepts during the next four years
  - Using NASA Ames and Langley resources
  - Contractor support
- Will deliver tested concepts to the FAA

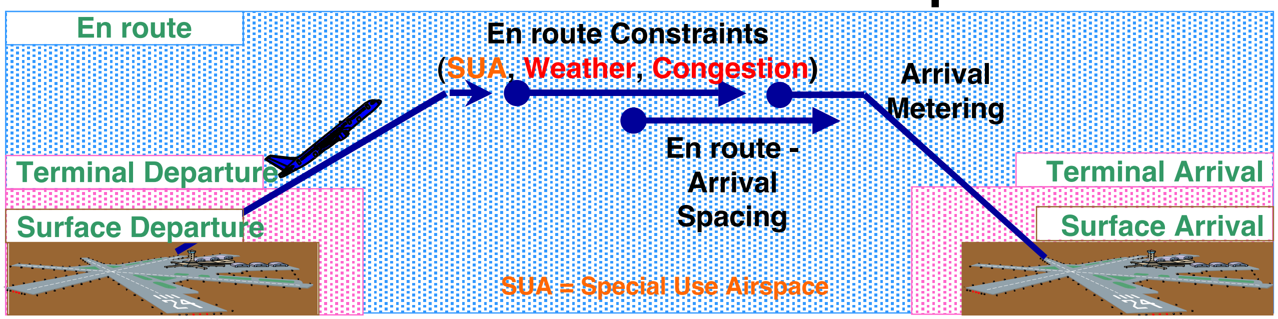
The DAG-TM Philosophy



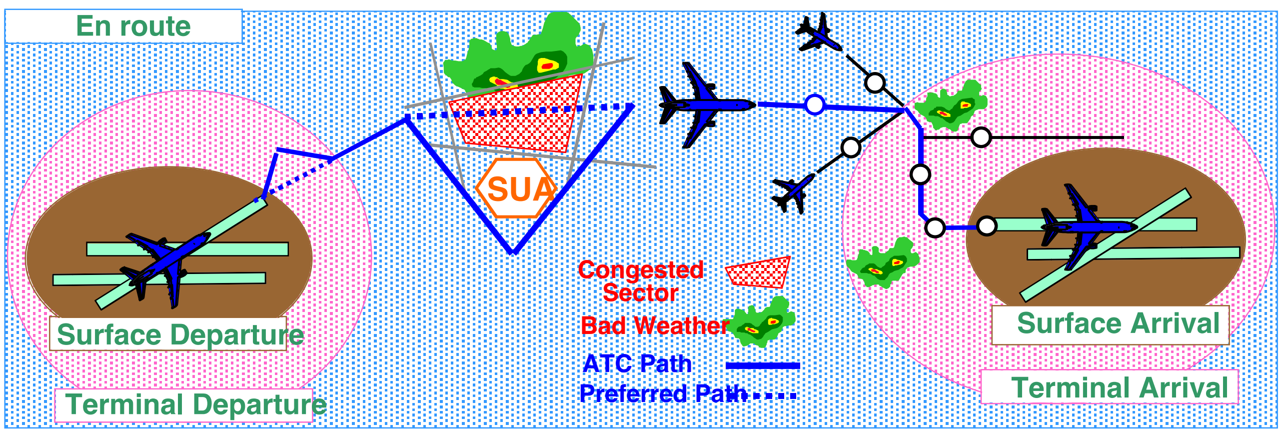
Better Air Traffic Management through Distributed:
Information - Decision Making - Responsibility

DAG-TM is a Gate-to-Gate Concept

- A matrix of gate-to-gate problems were defined by Ames, Langley, and Glenn researchers
- One or two DAG-TM-based concept element (CE) solutions were formulated to solve each problem



Concept elements are possible modes of operation within the scope of the RTCA Task Force 3 concept



The DAG-TM concept is comprised of 15 Concept Elements…

Concept Elements

Over-arching

Gate-to-Gate:
- CE-0 Data Exchange

Pre-flight

Pre-flight Planning:
- CE-1 User optimization for Constraints

Flight Operations

Surface Departure:
- CE-2 Intelligent [Taxi] routing

Terminal Departure:
- CE-3 Free Maneuvering for Separation
- CE-4 Trajectory Negotiation for Separation

En route: (Separation and local-TFM Conformance)
- *CE-5 (a/b) Free Maneuvering*
- *CE-6 (a/b) Trajectory Negotiation*

En route: (local-TFM)
- CE-7 Collaboration for SUA/Wx/Complexity

En route / Terminal: (local-TFM)
- CE-8 Collaboration for Arrival Metering

Terminal Arrival:
- CE-9 Free Maneuvering Around Weather
- CE-10 Trajectory Up link [to avoid] Weather

Terminal Arrival:
- CE-11 Self Spacing for Accurate Merge
- CE-12 Trajectory Exchange for Accurate Merge

Terminal Approach:
- CE-13 Closely Spaced Approaches

Surface Arrival:
- CE-14 Intelligent [Taxi] Routing

CE-5:
Free Maneuvering for User-Preferred Separation Assurance and Local Traffic Flow Management (TFM) Conformance

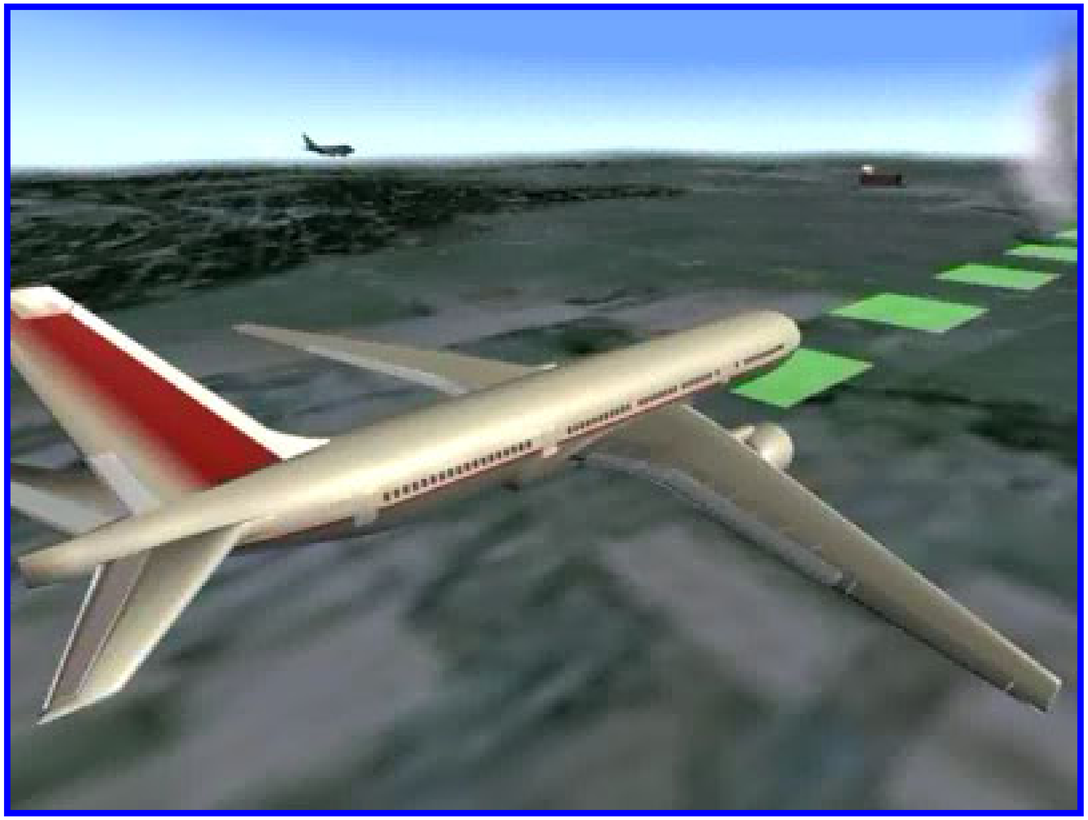
Problem:

- Air Traffic Service Provider (ATSP) cannot accommodate trajectory change requests due to workload
- ATSP-issued clearances often cause excessive deviations from user preferred trajectories (UPTs) for separation assurance or are otherwise not optimal for users

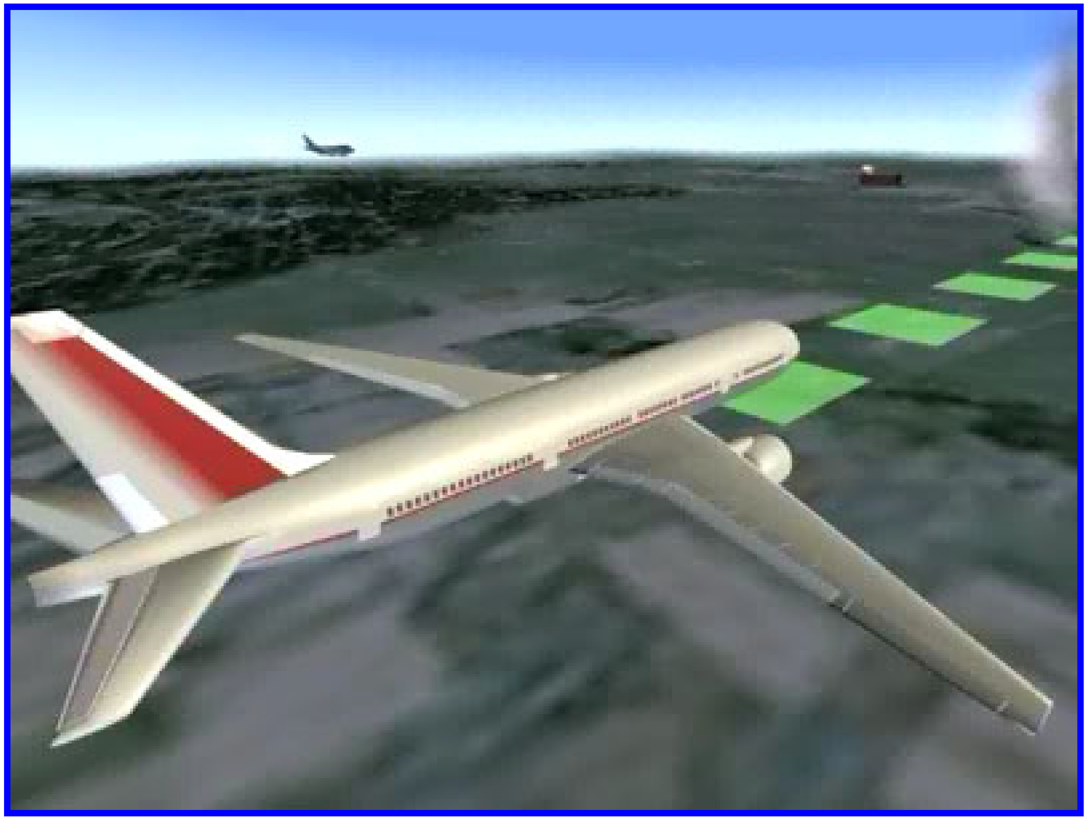
Solution:

- Air: Cockpit Display of Traffic Information (CDTI)-equipped aircraft maneuver freely for separation assurance
- Ground: ATSP monitors separation (with ground-based DSTs) and provides separation assurance for non-equipped aircraft

Today's System



CE-5 Concept



CE-6: En Route (&*Transition*) Trajectory Negotiation for User-preferred Separation and Local-TFM Conformance

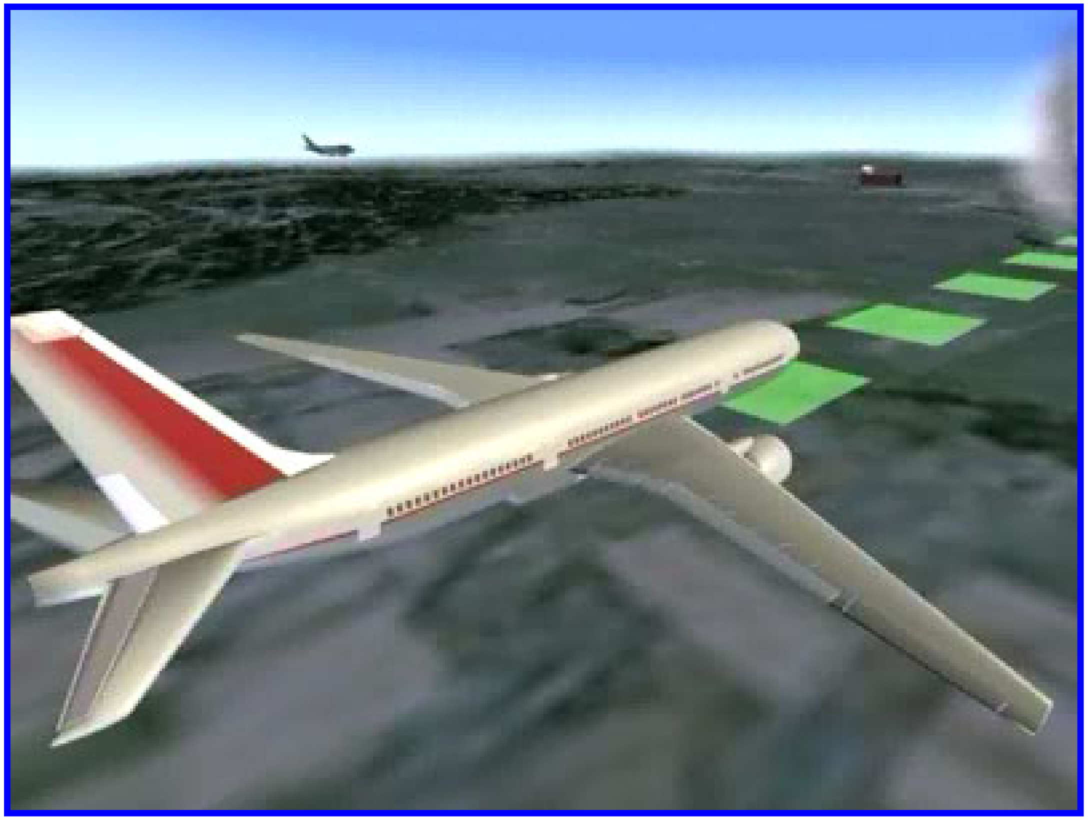
Problem:

- ATSP workload limits throughput and accommodation of UPTs
- ATSP-issued clearances often cause excessive deviations for separation assurance or are otherwise not preferred by users

Solution:

- User and ATSP negotiate for user-preferred trajectory changes:
  - User formulates UPT (based on constraints) and transmits to the ATSP
  - ATSP evaluates UPT for approval and amends constraints as needed
- CTAS-datalink-flight deck integration to facilitate:
  - Reduced datalink/CTAS input workload
  - Calibration of Flight Management System and CTAS
  - Trajectory-based clearances and improved flight conformance

CE-6 Concept



CE-11: Self-Spacing for Merging and In-Trail Separation

Problem:

- Excessive spacing buffers on final approach reduce arrival throughput and airport capacity
- Reduced visibility may limit airport acceptance rate

Solution:

- CDTI-equipped aircraft are cleared to maintain separation relative to a leading aircraft:
  - Flight has deck displays and guidance for:
    - Maneuvering
    - Self-merging and spacing
    - Fine tuning of fixed-time spacing
  - ATSP has displays and procedures for shared separation responsibility

Today's System

CE-11 Concept

DAG-TM Benefits

- CE-5
  - Self-management supports scalability of system
- CE-5 & 6
  - Increased user flexibility / efficiency within the presence of conflicting traffic and dynamic en route constraints
  - Shift/reduction in ATSP workload
  - Reduced excess separation buffers
  - Reduced voice communications
- CE-11
  - Reduced voice communications
  - Reduced controller workload for maintaining traffic separation
  - Increased arrival throughput

NASA DAG Research

- NASA Ames, Langley, and Glenn collaborating on DAG work
  - Ames focusing on air traffic control (ATC) or ground DST and procedures development
  - Langley responsible for flight deck DST and procedures research
  - Glenn researching communications infrastructure
- Initially pursuing parallel research
- Leading to air/ground integration studies to assess the feasibility of each concept
- Benefits data will also be collected in controlled experiments

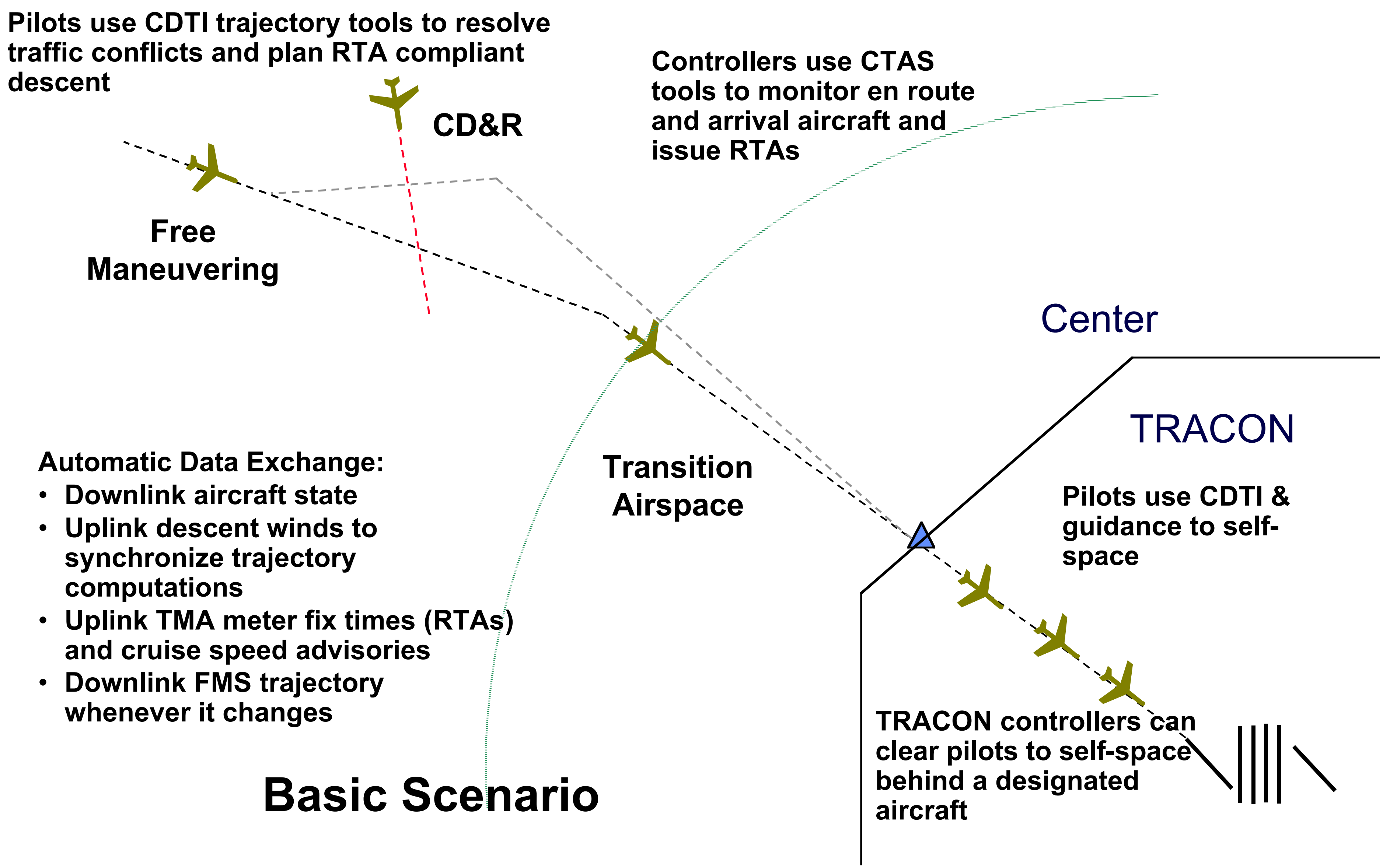
Current NASA Ames Research

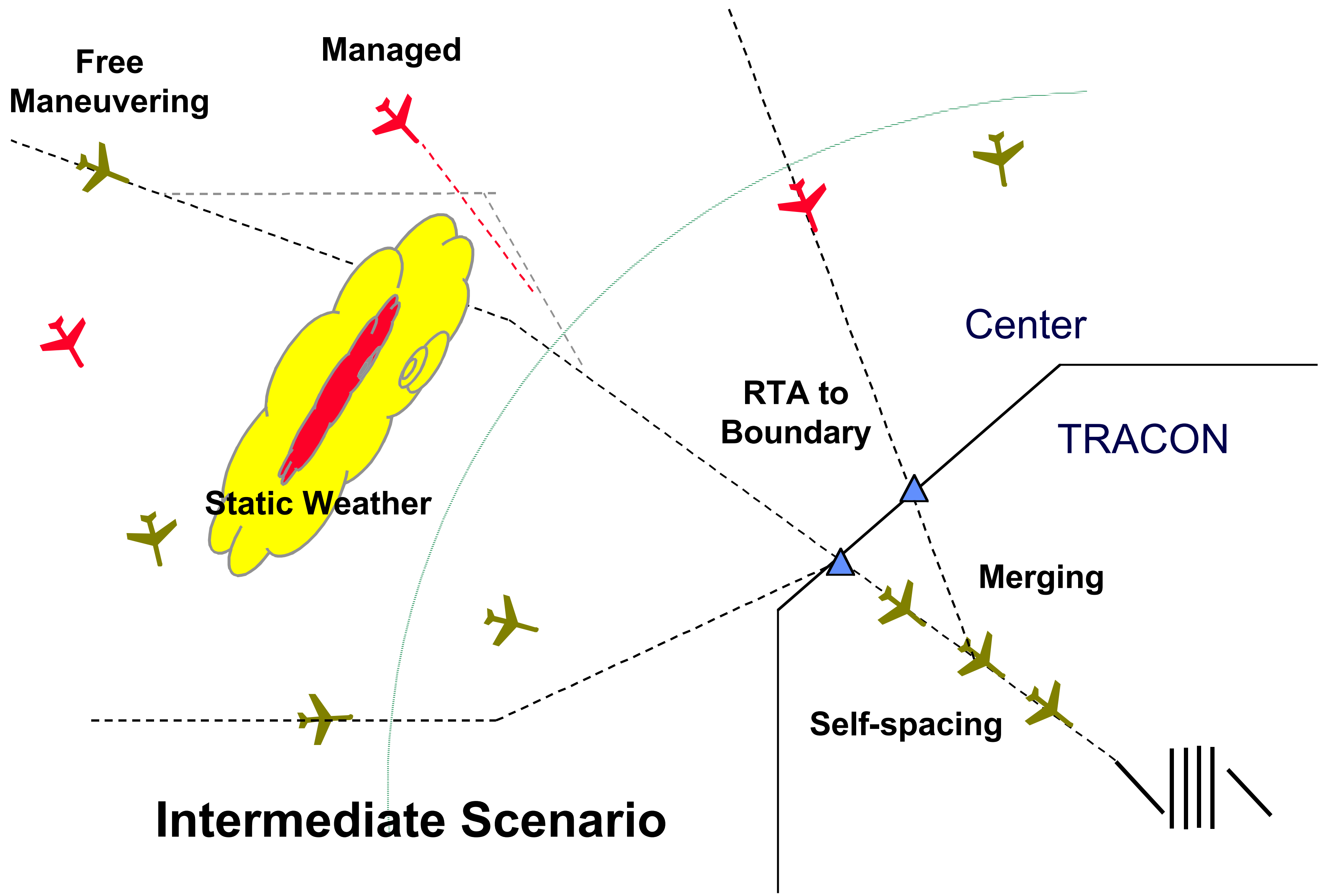
- Focusing on ATC component of DAG-TM CEs-5, 6, and 11
- Goal is to demonstrate initial feasibility of CEs
- Basing research on Concept Descriptions
- Filling out and evolving the concepts as research progresses
- Continuously involving operational people and stakeholders
- Incrementally building laboratory capabilities to address CEs
- Adding to complexity each year
- Following details are in process and subject to change

Ames Research Concept

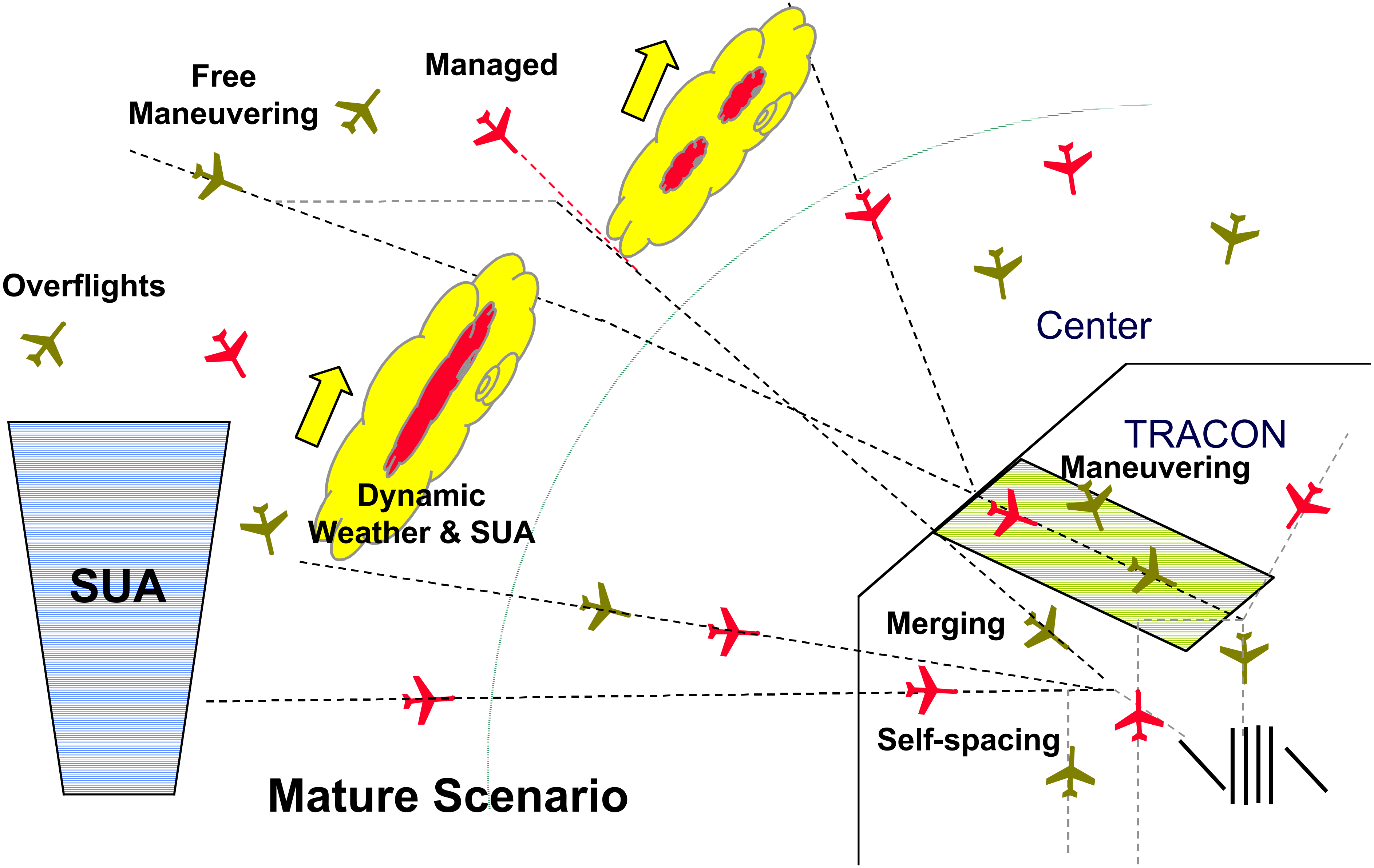
- The following scenarios are being used to test CEs-5, 6, and 11
- The Basic Scenario is being augmented this year with additional traffic, complexity, weather, and procedures
- Demonstrations held in September 2001 and January 2002
- Next demonstration in June 2002
- Two week experiment in September 2002 to initiate evaluation of benefits and performance
- Goal is to complete the research by the end of 2004

Basic Scenario





Intermediate Scenario



Mature Scenario

Roles and Responsibilities: General Rules

Only One Entity is Responsible for Separation

- ATC has the sole authority to cancel self-separation
- Pilot can request the cancellation of free-flight

En Route Free Flight – Flight Crew Responsible

- Flight crew (upon acceptance) is responsible for separation assurance
- Flight crew can request ATC assistance for conflict resolution, flow control, and traffic management considerations

Transition Phase – Flight Deck Responsible

- ATC will provide Required Time of Arrival (RTA) advisory for meter fix
- Flight crew is responsible for separation and meeting RTA

TRACON Boundary – ATC Responsible

- Controller is responsible for separation
- Flight crew can be cleared to maneuver, merge, and maintain in-trail spacing
- Controller can revoke clearance at any time

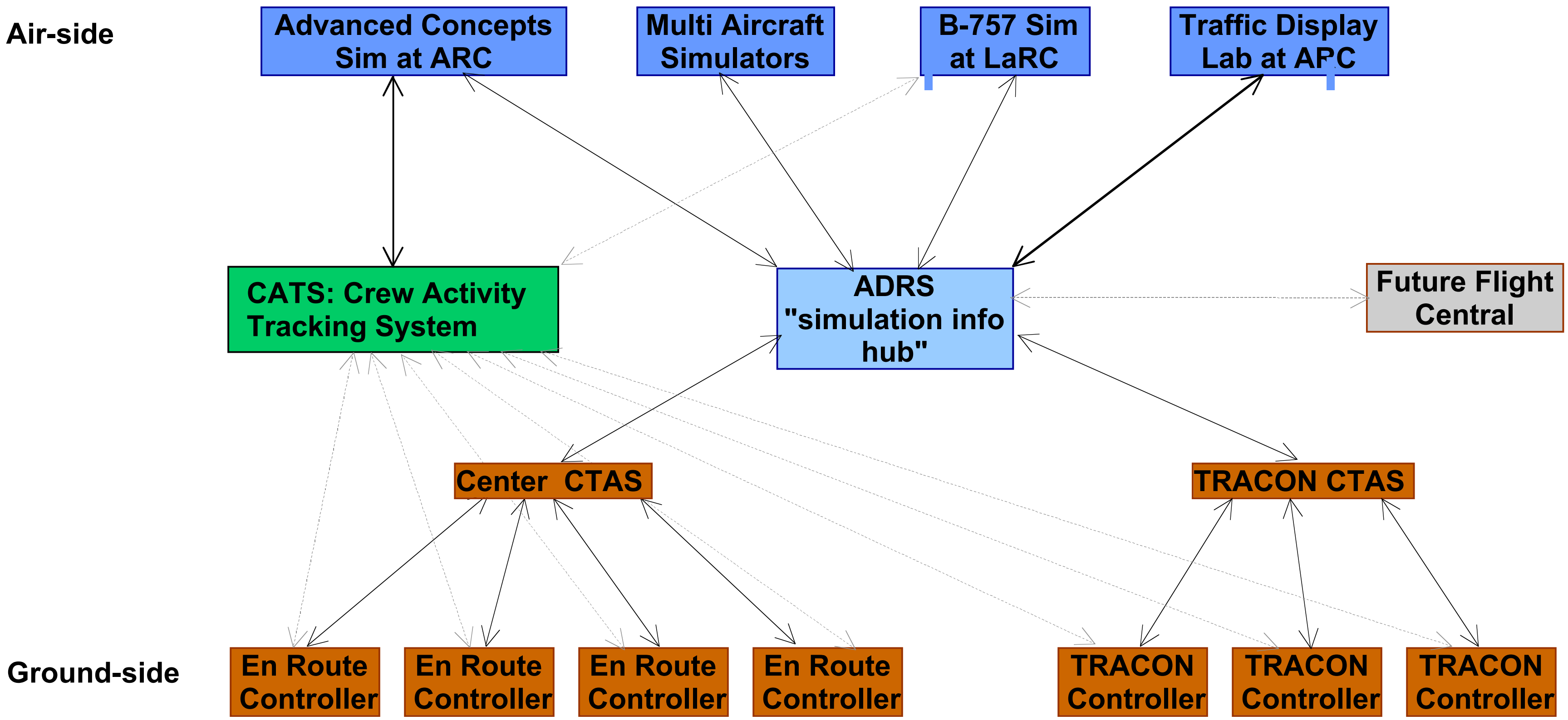
Ames Research Facilities

- Flight simulator
- Airspace Operations Lab
- Cockpit Display of Traffic Information

Crew-Vehicle Simulation Research Facility

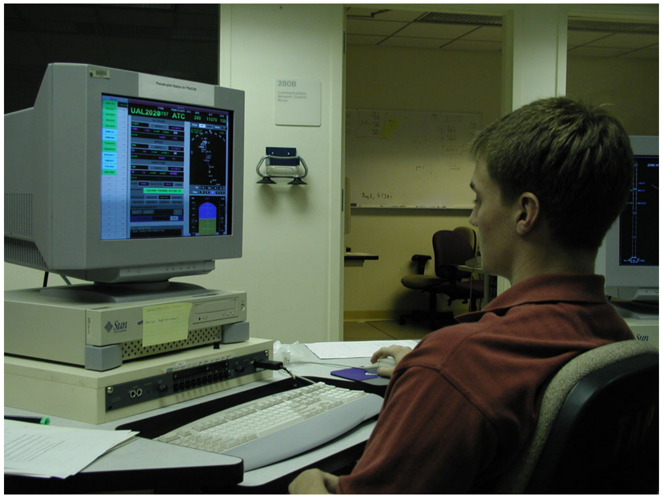
Advanced Cab

Airspace Operations Lab (AOL): Air/ground Simulation Capability for Human-System Research

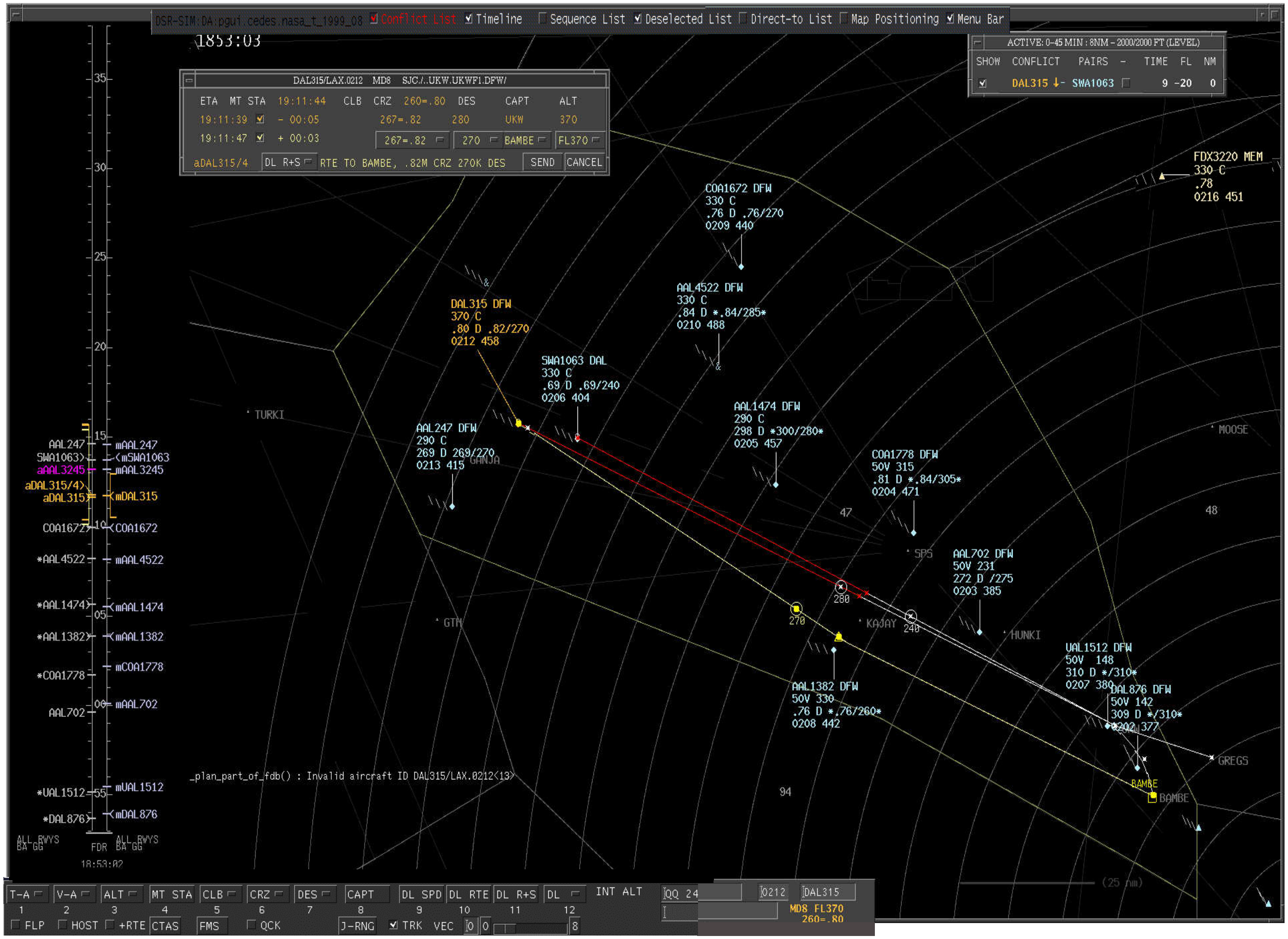


AOL Workstations

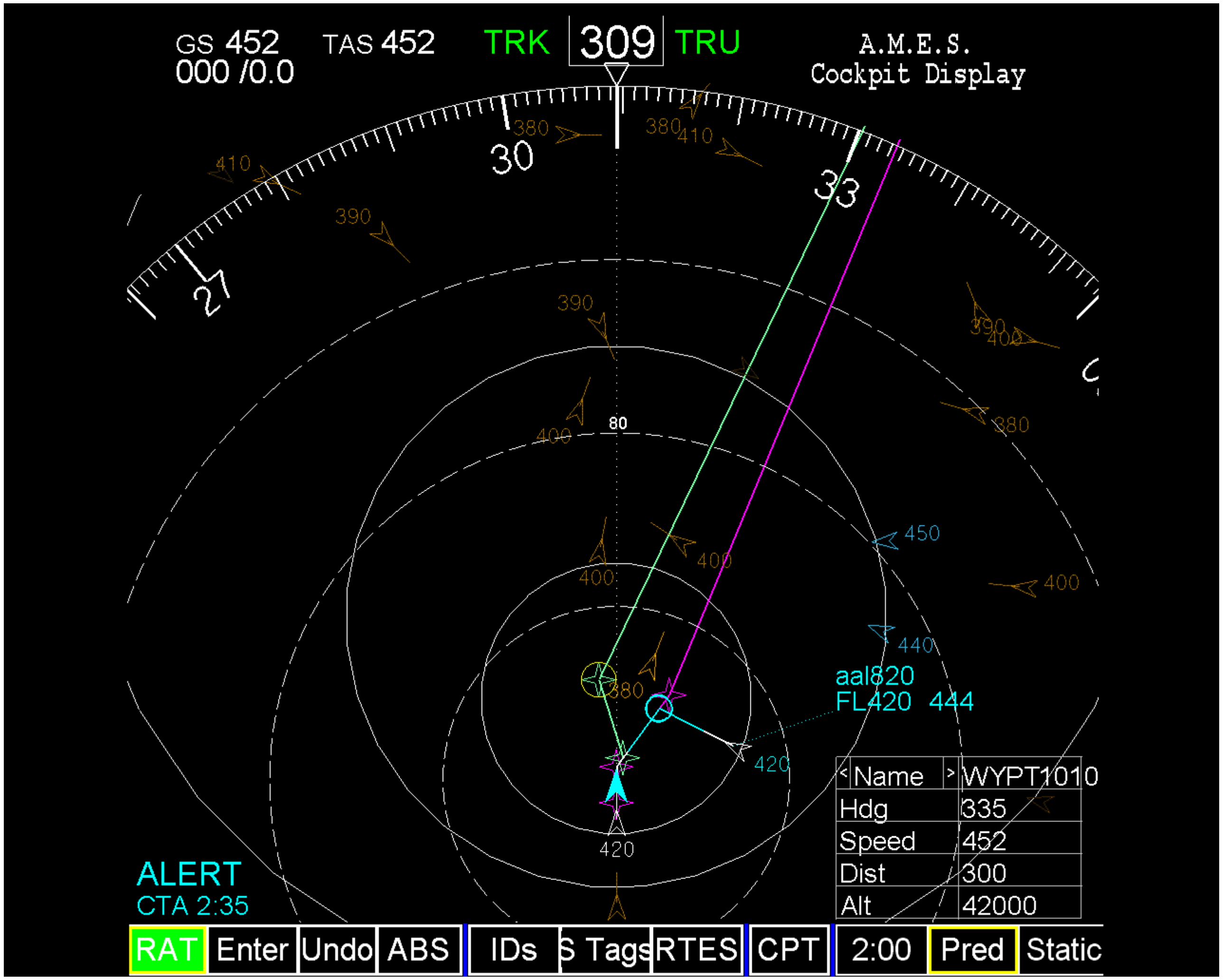




AOL Controller Display



CDTI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NASA Langley DAG-TM Research

- Developing flight deck tools and procedures for CE-5 and CE-11
- Conducted two recent experiments:
  - Airborne Use of Traffic Intent Information (AUTRII), focusing on quality of intent information
  - Advanced Terminal Area Approach Spacing (ATAAS), terminal arrival self spacing study
- Continuing with airborne DST development to support DAG concept element feasibility research

Airborne Use of Traffic Intent Information (AUTRII)

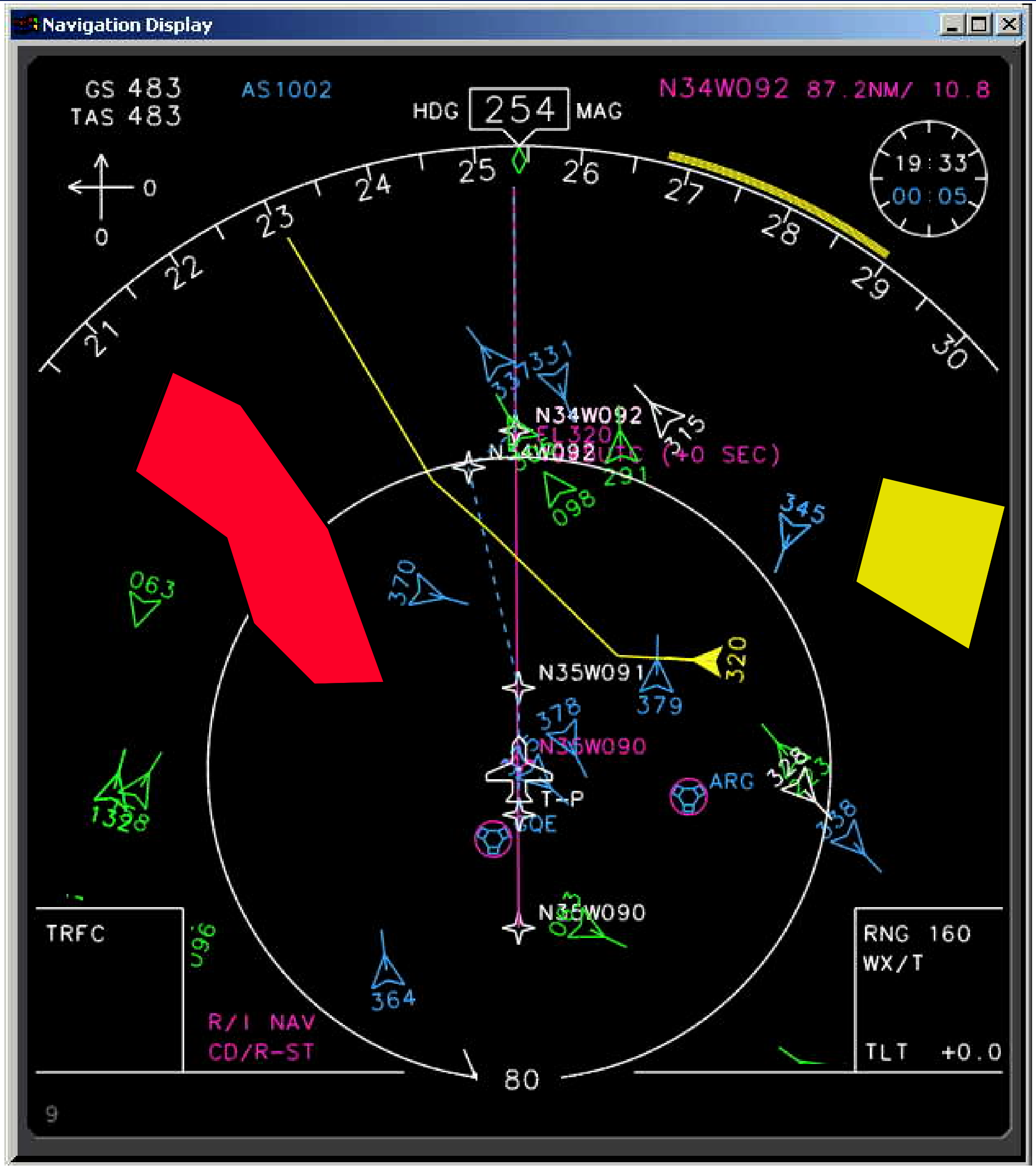
- Evaluated pilot capability to perform airborne self-separation in presence of flow constraints
- Investigated *advisability* of exchanging of intent information between autonomous airborne operators
- Evaluated utility of initial airborne decision support and CDTI functions
- Evaluated pilot acceptance of role expansion to include separation responsibility

Comparison of Two Operational Modes

- Tactical Mode
  - Based on exchange of *state* information only
  - Near-term conflict detection (5 minutes)
  - Maneuvers implemented manually through Flight Control Panel
- Strategic Mode
  - Took advantage of Flight Management System (FMS) guidance and performance database
  - Incorporated *state* and *intent* information in conflict detection
  - Longer-term conflict detection (nominal 20+ min.)
  - Maneuvers implemented manually or through FMS guidance

CDTI developed for AUTRII combines features from NASA Ames, NLR, and NASA Langley:

- Resolution advisories
- Conflict alerting symbology
- Conflict prevention “no-go” bands on heading, speed, and vertical speed scales
- Required time of arrival
- Predictors / flight plans
- Autonomous vs. managed aircraft
- Tail tag altitude - absolute / relative
- Altitude filter
- Climb / descent symbology
- Area hazard display



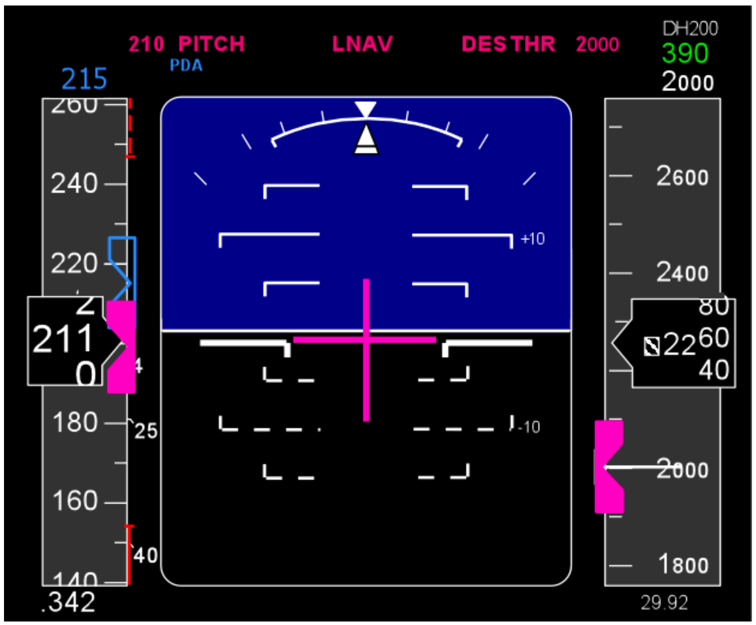
AUTRII Summary

- Initial Conclusions
  - Pilots met constraints in both strategic and tactical modes
  - Operational complexity did not affect pilot performance
  - Pilots preferred strategic mode (with state & intent information)
  - Display features were effective
- Additional Data Recorded for Analysis
  - Complete trajectories as flown
  - Pilot actions (maneuvers, display manipulations)
  - Workload measures (objective, subjective)
- Plans for Continued Research
  - Display evolution: vertical CD&R, weather conflicts, dark screen design
  - Descent CD&R with crossing restrictions

ATAAS Simulation Study Objectives

- Pilot evaluation (acceptability) of:
  - Approach spacing tasks (including charts, procedures and use of ATAAS system)
  - ATAAS user interface
- Pilot assessment of workload with different levels of automation
- Evaluation of algorithm performance when implemented on "real-world" equipment

ATAAS DST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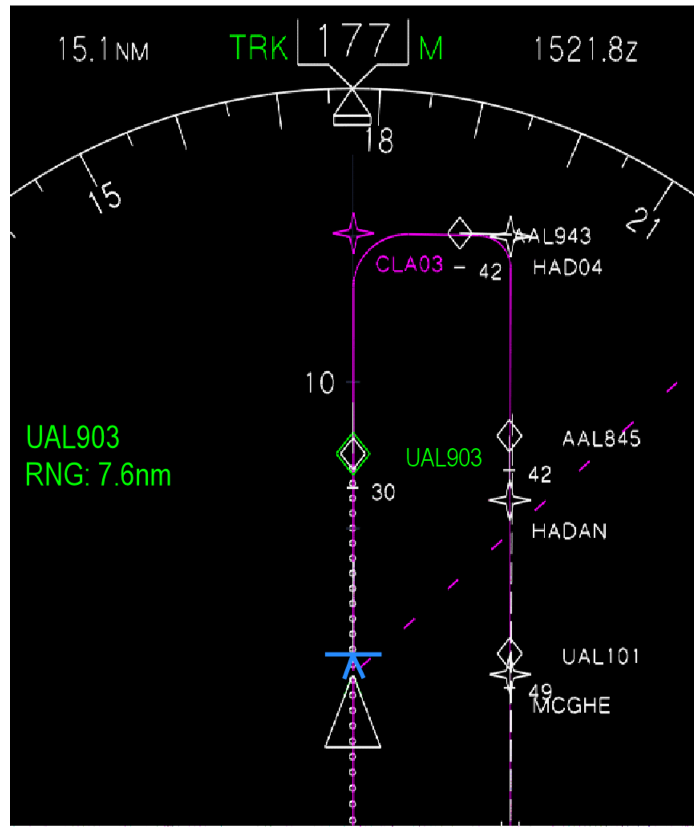
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Summary of Preliminary ATASS Results

- Algorithm performance
  - Spacing interval within one second of target when ATAAS speed guidance coupled with FMS
  - Spacing interval within 5 seconds when pilots followed speed commands with manual throttles or MCP
  - Standard deviation 1.3 to 1.7 seconds for the different control modes

Preliminary Post-Run Subjective Ratings

- **Pilots rated workload for ATAAS approach comparable to standard approach procedures**

  (1=much lower, 4=the same, 7=much higher):

	Physical	Mental	Overall
Mean	**3.8**	**3.9**	**4.0**
Std. Dev.	**1.2**	**1.2**	**1.1**

- **Pilots rated head-down time acceptable**

  (1=not at all acceptable, 4=borderline, 7=very acceptable):

	Downwind	Base	Final
Mean	**5.8**	**6.0**	**6.2**
Std. Dev.	**1.5**	**1.2**	**0.9**

NASA Langley Research Facilities

- Air Traffic Operations Laboratory
- Flight Simulators
- B-757 Aircraft

LANGLEY RESEARCH CENTER

Air Traffic Operations Laboratory

Subject Pilots

Air Traffic Controllers

Background Traffic Simulation

Simulation Manager / Researchers

Batch Pilot Stations

LaRC Flight Deck Simulators

Research Flight Deck

Integration Flight Deck

Langley B757 Test Aircraft

The End